DOCUMENT RESUME

ED 255 384 SE 045 480

AUTHOR Betkouski, Marianne B.; McDonald, Sandra Kirk
TITLE A Study of Differential Problem Solving Behaviors in Processing a Science Text Passage.
PUB DATE 85
NOTE 18p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (58th, French Lick Springs, IN, April 15-18, 1985).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Biology; Cognitive Processes; *Concept Formation; Error Patterns; High Schools; *Problem Solving; *Reading Comprehension; Science Education; *Secondary School Science
IDENTIFIERS *Misconceptions; Science Education Research

ABSTRACT

This study investigated how students processed information obtained by reading a passage related to inertial reference frames. Two groups of 10th-grade students (one group consisting of students identified as potential National Merit Scholars and another consisting of students enrolled in level-I biology) read a science text passage and answered a set of six questions requiring that they apply the new material to novel situations. Results show that the academically talented students achieved higher scores than the level-I biology students. Other results were obtained from analyses of tape recorded interview data about how students processed each question. Test questions were specifically designed to reveal problem-solving strategies and allow for error pattern analysis. The academically talented students were more verbal, more methodical in comparing questions to the passage, and more likely to relate questions or parts of the text to their own past experiences. The average students often looked for a literal match between the questions and the text, and were more likely to answer questions based on previously held "naive theories," which sometimes were in direct conflict with text material. These results suggest that caution is needed in assuming that students will learn effectively from text presentations of new concepts. (Author/JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

ED255384

Authors

Marianne B. Betkouski, Ph.D.
Associate Professor, Division of Curriculum and Instruction
University of North Florida
P.O. Box 17074
Jacksonville, Florida 32216

Ph.D., University of Texas, 1975

Sandra Kirk McDonald, Ph.D.
Associate Professor, Division of Curriculum and Instruction
University of North Florida
P.O. Box 17074
Jacksonville, Florida 32216

Ph.D, University of Florida, 1978

SE 045480

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Marianne B. Betkouski
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ABSTRACT

This study gathered protocol data related to how students process information obtained by reading a passage related to inertial reference frames. Two groups of tenth grade students, one of which consisted of students identified as potential National Merit Scholars, and another which consisted of students who were enrolled in Biology I in a large, middle SES high school, read a science text passage and then answered a set of six questions requiring that they apply the new material to novel situations. Raw and weighted test score data and reading times were compared, and as expected, the academically talented students achieved higher raw and weighted scores. A second focus of the study, however, was the analysis of the tape recorded interview data about how they processed each question. Interviews were conducted by the investigators in one-on-one situations, and verbatim transcripts of the interviews were made. Test questions were specifically designed to reveal problem solving strategies and allow for error pattern analysis. The academically talented students were more verbal, more methodical in comparing questions to the passage, and more likely to relate questions or parts of the text to their own past experiences. The average students often looked for a literal match between the questions and the text, and were much more likely to answer questions based on previously held "naive theories," which sometimes were in direct conflict with the text material. The results of the study suggest that caution is needed in assuming that students will learn effectively from text presentations of new concepts.

A STUDY OF DIFFERENTIAL PROBLEM SOLVING BEHAVIORS IN PROCESSING A SCIENCE TEXT PASSAGE

PURPOSE OF STUDY

The purpose of this study was to gather protocol data related to how 10th grade students process information after reading a passage related to inertial reference frames. Both qualitative and quantitative data were gathered and analyzed.

THEORETICAL BASIS

There is little disagreement today about the importance of concept formation and problem solving in science education. In the document "Educating Americans for the 21st Century," the National Science Board Commission on Pre-College Education in Mathematics, Science and Technology expanded their definition of basic skills to include higher level problem solving skills, and maintained that all students need these skills (Coleman, et al., 1983). However, the debate about how these skills should be taught ensues. Norman (1983) suggests that teachers should use models to help students construct their own mental models as representations of a new situation. These models should have these three characteristics: learnability, functionality, and usability. The model must not be too difficult to learn, it must predict the way a system really operates, and it must not exceed the short term memory capabilities of the learners.

The merging of findings emanating from cognitive science and science education research is creating mechanisms for describing the science learning process. Insights into these mechanisms can generate implications

for the teaching of science. A particularly cogent area of joint investigation is that of "naive theories" or erroneous pre-instructional perceptions of how the world works. Several naive theories of the physical world have been investigated and researchers are in agreement about the tenacity of these preconceived notions (Champagne and Klopfer, 1984; McCloskey, 1983; diSessa, 1983; Resnick, 1983). Even when students are presented with information which contradicts the theory, it is difficult to let go of the old theory and replace it with the currently accepted correct one. Students need to be convinced in a meaningful way, often with concrete data and experience with the phenomenon itself, that the new theory is better.

Naive theories seem to result from limited and incomplete experience with the phenomenon in question. For instance, Newton's Laws of Motion can be troublesome because they require the conceptualization of a frictionless universe. The Aristotelian concept of impetus seems to be more intuitive; when a ball is rolled across the floor it stops because it "runs out" of the original force imparted to it when it was rolled. That original force is much more tangible than the opposing force of friction which can stop an otherwise constant motion.

Background studies used in developing Project Synthesis (Harms and Yager, 1981) point to an overwhelming influence of the textbook in implementing science curriculum goals. Therefore, much of a student's background in developing concept formation and problem solving skills is delivered by means of textbook passages. Fifteen hundred biology teachers responding to a questionnaire indicated that the most important function

of the biology textbook is to provide students with content input (Spiegel and Wright, 1984). Even among teachers who professed to use materials developed under sponsorship of the National Science Foundation, few used the inquiry-oriented materials which were to accompany the texts (Anderson, 1981). Anderson goes on to state that a problem in teaching physical science is textbooks with limited instructional approaches.

Given that textbooks are widely used to develop content, what is currently known about how and what students learn from textbooks? Champagne, Klopfer, and Gunstone (1983) summarize the work of cognitive psychologists who have analyzed text comprehension. Sentence structure alone does not account for the comprehension. World knowledge or knowledge about the structure of the world also affects the process. World knowledge is usually acquired developmentally. Studies show that world knwoledge schemata are generally facilitative in learning. However, in the learning of physics, world knowledge is often at odds with accepted physics principles. Possible reasons for this occurrence are the imprecise everyday use of physics terms (e.g., speed, velocity, and acceleration) and the limited real world experiences of students. Hence, it is not surprising that naive theories emerge.

In summary, research has shown that student preinstructional knowledge can interfere with the learning process. When trying to incorporate new information into memory, the student interprets the new information in the context of his/her preinstructional set. As is indicated from a study of protocol data, students will not process or remember parts of explanations which conflict with tenacious naive theories. (Champagne, Gunstone, and Klopfer, 1983)

Since much of a student's instruction in science is delivered by means of the textbook and since the student's preinstructional state affects his perception of new information, a legitimate area of research is the investigation of information processing strategies used by students when exposed to a novel concept in a brief written format using real world examples.

PROCEDURE

Subjects were required to read a text passage and then answer questions requiring application of the knowledge in novel situations. The task was designed to reveal problem solving strategies. The subjects were tenth grade students in a large metropolitan school system. Group 1 (control group) was selected from students enrolled in Biology I at a large middle SES high school. Group 2 (experimental group) consisted of 18 students who had been previously identified as potential National Merit Scholars based on previous achievement test scores. These students were considered academically talented, and in general were enrolled in higher level science courses. The task was identical for both groups. The students were brought to the university campus on two succeeding Saturday mornings, with all Group 1 students attending on the first day and all Group 2 students on the second.

Initially, the subjects completed an information sheet; they were then divided into small groups to complete the task, the first part of which consisted of reading a four page passage introducing the concept of inertia. This topic was chosen because it was assumed that using a physics topic would reduce the effects of prior classroom knowledge, as none of the subjects had taken a physics class at this point in their academic programs. Each student was taken individually to an unoccupied classroom for this

task, and was alone there except for the presence of the interviewer.

Immediately after reading the passage the student was asked to answer six posttest questions requiring understanding of the concept and application of it in novel situations. Each question was designed so that one of the answers was exactly correct, and a second answer was "almost correct." The distractors were carefully written to include commonly held misconceptions. The student was allowed to use as much time as he/she wished to read the passage and answer the questions, and could refer back to the text as often as necessary. The student's reading and question response times were recorded by the interviewer. After completing the questions, the student was interviewed using an open ended, structured questioning series designed to reveal problem solving strategies. The interviewer gave no indication of correctness or incorrectness of response. The interviews were tape recorded and a verbatim transcription was prepared.

RESULTS

Data consisted of quantitative results of the posttest and the transcriptions of the interviews. The posttest yielded raw scores based on the selection of the correct response to the six items and a weighted score which was derived from the students' selection of the "next best" answer for each of the questions. Weighted scores could potentially range from 0 to 42. The reading times were also compared and are included in Table 1.

- Insert Table 1. about here -

As would be expected, Group 2 achieved higher raw scores and weighted scores on the posttest. Less predictably, Group 2 students spent considerably more time reading and answering the questions. No independent measure of reading speed on comprehension was used, but it is reasonable to conclude that the academically talented students chose to read and work more slowly.

The information gained from the transcriptions of the interview yielded consistent patterns in both groups. The academically talented students were much more verbal, more likely to have used methodical strategies in comparing the questions to the reading passage, and more likely to have related their new knowledge to past experiences. The control group students often looked for a literal match between the question and the text, and were much more likely to answer questions based on a "naive theory" which was in direct conflict to the text passage. However, when groups adhered to naive theories, they were similar.

DISCUSSION OF RESULTS

Error pattern analysis is useful as a means to diagnose student learning problems. The following is a discussion of error patterns substantiated by protocol type data. See appendix for the test instrument used.

Item 1 asked that the forces in a whirling bucket of water be identified. Even though an analogous example was diagrammed on the same page containing the question, 7 students in the control group and 2 in the experimental group chose an answer that was neither the best nor the second best. The figure

- Insert Table 2 about here -

chosen by a total of 8 students illustrated balanced forces (response "a"), which students reasoned would be necessary to keep water in the bucket. The

concept of balance took precedence over the explanation of unbalanced force and accelerated motion in the passage.

Item 2 shows a ball acted upon by four balanced forces. All students chose either the correct or second best answer, although only one control group student answered the question correctly. Twenty-three students in all chose an intuitive answer which illustrated an incomplete understanding of Newton's Law of Inertia (response "a"). They interpreted balanced forces as a state of rest, not expanding their concept of balanced forces to include motion in a straight line.

Item 3 asked the students to imagine that they were riding on a ball attached to a string being whirled around and to choose a description of their situation. Although 13 experimental students chose the correct answer (response "a"), five students in that group and five in the control group chose answer "d", an intuitive answer but one which belies the concept of centripetal force. Of the remaining control group students, five chose the correct answer and five more chose answers which showed a lack of understanding of the definition of inertial reference frames.

Item 4 was the most difficult if judged by number of correct responses. The question refers to a ride at the fair where riders are pinned to the wall of a spinning cylinder as the floor drops out. Only three experimental students and none in the control group chose the correct answer (response "c"). The most popular incorrect response was given by twelve students in the experimental group and twelve in the control group (response "b"). The response illustrates a naive approach - a force was needed to push the riders against the wall. The response was chosen in spite of the fact that

the passage stated that centrifugal force is merely a perceived force. Apparently the passage provided insufficient meaningful evidence to allow students to give up the naive theory. Several students referred to their own experiences on the ride. When asked why the answer was chosen (in this case "b" - the most popular incorrect response), one student replied, "My own experience riding on that ride. When I went on it I already knew why I stayed against the wall, because the centrifugal force just pushed me back. If there was no centrifugal force I would just fall and go in circles . . ."

Item 5 has the students imagine that there is no such thing as friction, admittedly difficult to do. A ball has been thrown and is moving along the floor. Students are to choose a diagram depicting forces on the ball as it is rolling. Six experimental and three control group students chose the correct response ("a"), the ball alone. Eleven experimental students and nine controls chose the answer which illustrates a classic naive theory of motion, i.e., a force or "impetus" is needed to keep the ball rolling (response "b"). The correct answer was interpreted as a state of rest by these students. The following comment by a control student illustrates confusion when trying to link the answer chosen with part of the passage: "It says right here in the last sentence, the force stops as soon as the ball leaves your hand, in some way. I can't explain it. It's the same thing, durn, but I can't explain it."

Item 6 asks the students to choose a diagram showing the path of a ball which is being whirled around on a string <u>after</u> the string breaks. Most students chose the correct answer (response "b"). The error patterns were identical in both groups, with four students choosing an answer that

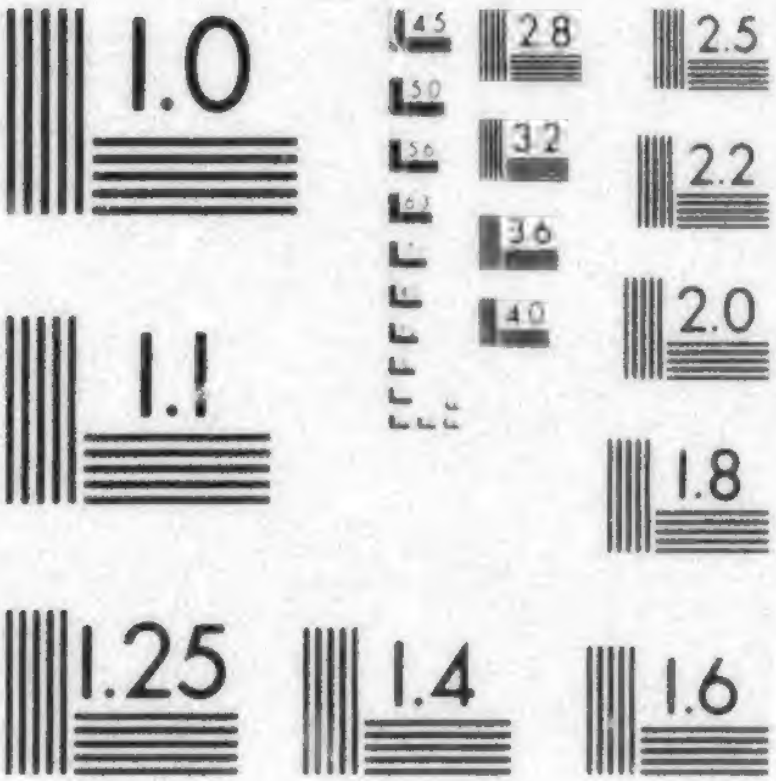
illustrated only a partial understanding of Newton's Laws, i.e., the ball would continue moving along a curved path. One student in each group had the ball moving in an opposite path (response "c").

Overall it was apparent that in most cases new concepts like inertia and centipetal force were only partially understood. A mixture of personal experience and limited understanding were the basis for many item choices. In some instances, students would use a familiar term incorrectly to explain a choice. For instance, when explaining why riders are pinned to the moving cylinder in #4, a student answered, "The gravity of the earth is holding the people to the wall . . ."

SUMMARY AND IMPLICATIONS

Resnick (1983), in describing the process of learning science and mathematics, suggests that learners bring to formal learning experiences extensive "naive theories" about how the world works. Further, the learners are reluctant to give up their ideas in favor of those which the teacher is trying to deliver. These "naive theories" are extremely difficult to replace with the scientific theories that are being taught in the classroom. This study reinforces the existence and tenacity of naive theories.

Resnick suggests that such naive theories must be directly confronted. "Students may have to be forced to pit their theories against the ones they are being asked to learn, to deal with conflict between theories in much the way scientists do." (Resnick, 1982). DiSessa (1983) indicates that novices apply rules without knowing when the rules do not apply or when they provide an incomplete explanation. This study provides further insight into what students are thinking as they read about new rules.



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No 2)

There are direct implications of this study, both in terms of students' relative inability to learn new concepts from text and in terms of teaching problem solving strategies. The study suggests that we need to be cautious in assuming that students will learn effectively from reading assignments. The students in this study, especially those that were less capable, did not use the text material well even when they could refer back to it at will. Sometimes it appeared that they answered in the questions "in spite of" what they had read.

A perusal of physical science and physics texts corroborates other reports which indicate that texts reinforce a novice approach to learning physics, i.e., they present rules or equations without a qualitative analysis of how these components relate to one another and to the discipline of physics as a whole. Novices seek a match to pictures and equations without really analyzing the problem. Links, connections, and convincing real world examples are missing. One text makes a statement: "You have seen that acceleration is directly proportional to the force applied." However, the "seeing" consists of seeing those words on the printed page, but not meaningfully seeing how these concepts (force and acceleration) are related.

Texts in general do not of themselves promote meaningful learning. Further investigation is needed to determine what forms of direct instruction in the use of models presented in a text passage would enhance the students' use of the material in problem solving. In-service instruction in confronting naive theories and using textbooks would appear to be areas of need for the classroom teacher.

TABLE ONE
RAW SCORES AND WEIGHTED SCORES BY SUBJECT

SUBJECT	READ TIME	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	RAW SCORE	WGTD SCORE
1	17	0	0	0	0	0	1	1	20
2	8	1	0	1	0	1	1	4	31
3	10	0	0	0	0	0	1	1	11
4	12	0	0	1	0	0	1	2	24
5	7	1	1	1	0	0	1	4	31
6	12	0	0	0	0	0	1	1	17
7	8	0	0	0	0	0	1	1	18
8	14	1	0	1	0	0	1	3	29
9	7	1	0	0	0	0	0	1	15
10	8	0	0	0	0	0	1	1	18
11	8	0	0	0	0	0	0	0	13
12	13	1	0	0	0	0	0	1	17
13	9	1	0	0	0	1	0	2	29
14	9	0	0	0	0	1	1	2	24
15	10	0	0	1	0	0	0	1	12
20	13	1	1	0	1	0	0	3	28
21	22	1	0	1	0	0	1	3	29
22	14	1	0	0	0	0	1	2	27
23	19	0	0	1	0	0	1	2	20
24	19	1	1	1	1	1	1	6	39
25	11	1	0	1	0	0	0	2	29
26	13	1	1	1	0	1	1	5	33
27	15	1	0	1	0	1	1	4	30
28	11	1	1	1	1	1	1	6	39
29	20	0	0	1	0	0	1	2	21
30	16	1	0	0	0	0	1	2	25
31	16	0	1	0	0	0	0	1	20
32	13	1	1	1	0	0	0	3	28
33	16	1	0	1	0	0	1	3	29
34	13	1	1	1	0	1	1	5	35
35	9	0	1	1	0	0	1	3	24
36	9	1	0	0	0	0	1	2	20
37	14	1	1	1	0	1	0	4	29

CONTROL GROUP SUBJECTS 1-15

EXPERIMENTAL GROUP SUBJECTS 20-37

BEST COPY AVAILABLE

TABLE TWO

NUMBER OF SUBJECTS CHOOSING EACH RESPONSE

	EXPER.	CONTROL	TOTAL
ITEM 1			
A	2	6	8
*B	2	2	4
C	0	1	1
**D	14	6	20
ITEM 2			
*A	9	14	23
**B	9	1	10
C	0	0	0
D	0	0	0
ITEM 3			
**A	13	5	18
B	0	4	4
*C	0	1	1
D	5	5	10
ITEM 4			
*A	1	2	3
B	12	12	24
**C	3	0	3
D	2	1	3
ITEM 5			
*A	11	9	20
B	1	2	3
**C	6	3	9
D	0	1	1
ITEM 6			
A	4	4	8
**B	13	10	23
*C	1	1	2
D	0	0	0

**INDICATES CORRECT RESPONSE
*INDICATES SECOND BEST RESPONSE

BEST COPY AVAILABLE

REFERENCES

Anderson, R.D. Physical science education. in Harms, N.C. and Yager, R.E. What Research Says to the Science Teacher. Washington, D.C., National Science Teachers' Association, 1981.

Champagne, A.B. and L.E. Klopfer. Research in science education: the cognitive psychology perspective. in Holdzkom, D. and Lutz, P.B. Research Within Reach: Science Education. Washington, D.C., National Institute of Education, 1984.

Champagne, A.B., Klopfer, L.E. and R.F. Gunstone. Cognitive Research and the Design of Science Instruction. Pittsburgh, University of Pittsburgh Learning Research and Development Center, 1983.

Champagne, A.B., Gunstone, R.F. and Klopfer, L.E. Naive knowledge and science learning. Research in Science and Technological Education, vol. 1 (2) 1983.

Coleman, W.T., and C.C. Selby. NSB Commission on Precollege Education in Mathematics, Science, and Technology. Educating Americans for the 21st Century: A Plan of Action for All American Elementary and Secondary School Students So That Their Achievement is the Best in the World by 1995, Washington, D.C., National Science Foundation (Eric/SE 043 150), September, 1983.

diSessa, A.A., Phenomenology and the evolution of intuition. in Gentner, D. and A.L. Stevens,(eds) Mental Models, Hillsdale, N.J., Lawrence Erlbaum Associates, 1983.

Harms, N.C. and R.E. Yager. What Research Says to the Science Teacher. Washington, D.C., National Science Teachers' Association, 1981.

McCloskey, N. Naive theories of motion. in Gentner, D. and A.L. Steven, (eds) Mental Models. Hillsdale, N.J., Lawrence Erlbaum Associates, 1983.

Norman, D.A. Some observations on mental models. in Gentner, D. and A.L. Stevens, (eds) Mental Models. Hillsdale, N.J., Lawrence Erlbaum Associates, 1983.

Resnick, L.B. Mathematics and science learning: a new conception. Science, 220, April 29, 1983, 122-123.

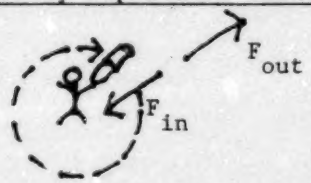
Spiegel, D.L. and J.D. Wright. Biology teachers' preference in textbook characteristics. Journal of Reading, Vol. 27 (7), April, 1984.

APPENDIX
POST-TEST

CONSIDER WHAT YOU HAVE JUST READ AND ANSWER THE FOLLOWING QUESTIONS.

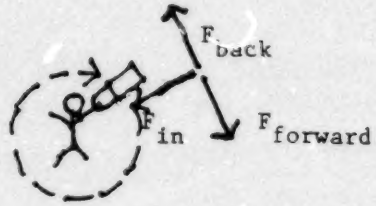
Circle the letter of the best response.

1. As children we sometimes had fun taking a bucket of water and whirling it around and around and seeing that the water didn't come out. Assume you're whirling the bucket at constant speed. Which of the following most accurately represents the forces on the bucket?

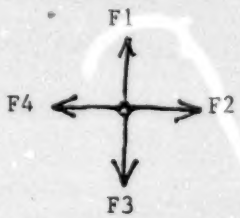
A) 

B)

C)

D) 

2. Imagine you're looking down at a ball from above. The ball has the four forces acting on it as shown in the diagram.



Which of the following discribes the motion of the ball in the diagram above?

a. The ball must be at rest since it is being acted upon by evenly balanced forces.
b. The ball is either moving in a straight line at constant speed or is at rest.
c. The ball's motion is non-inertial.
d. The ball is being acted upon by centripetal force in two directions.

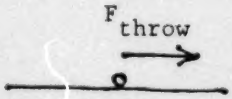
3. In the passage you read, there was a description of a ball tied to a string being whirled around. Imagine that you were riding on the ball. Which of the following discribes you situation?

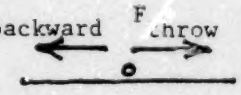
a. You are in a non-inertial reference frame and therefore you would feel the force which is described as centrifugal force.
b. The same forces which are acting on the ball are acting on you so you are in an inertial reference frame.
c. You are traveling at constant speed so you are in an inertial reference frame.
d. You are experiencing a centripetal force which would throw you outward off the ball.

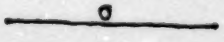
4. You may have watched or ridden on the ride at the fair in which people stand against the wall of a giant cylinder. The cylinder starts to spin, and then the floor drops out. Instead of falling to the ground, however, all the riders remain pinned to the wall. Based on what you just read, which of the following explains why the riders do not fall?

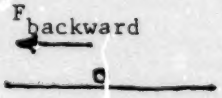
a. The riders are moving at a constant speed around the sides of cylinder, so the motion is inertial and they do not fall.
b. Centrifugal force pushes them outward against the walls, and therefore they do not fall.
c. Centripetal force is being provided by the walls of the cylinder.
d. The centrifugal force outward exactly balances the centripetal force inward so they move at constant speed and do not fall.

5. Imagine for now that there is no such thing as friction. Now further imagine that a ball has been thrown and is rolling along on a smooth frictionless floor after the throw. Which of the following most accurately represents the forces on the ball as it is rolling?

A) 

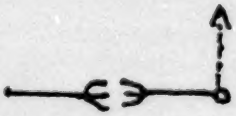
B) 

C) 

D) 

6. Imagine you're whirling the ball and string around your head and the string suddenly breaks. Which of the following most accurately describes the path of the ball after the string breaks? Assume you're looking down on the ball from above.

A)

B) 

C)